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Challet, D., Marsili, M., and Zhang, Y.: *Minority Games: Interacting Agents in Financial Markets.* I, 344 pp. Oxford University Press, Oxford New York 2005. Hardcover £ 45.00

In many situations an agent faces the problem of whether he wants to belong to the minority or to the majority of a collection of other agents, in a financial market for example. He decides according to a set of strategies he has in mind. If he wants to buy an asset, it is worthwhile for him to be in the minority of those who are interested in the asset, since then the price to buy would be low, while if he wants to sell an assets, he wants to be in the majority of interested agents, since then the price to sell might be high. The Minority Game focuses on the minority aspect and is a stylized model of such a mechanism. Fluctuations generated by this decision process are the main topic to be studied within the framework of Minority Games. It would be of enormous help to the agent's decision, if he could predict the system. Predictability of a complex system is generally only possible in a statistical sense. An agent only observes a single realization of price trail. There is evidence that in the Minority Game a single realization already suffices to predict large future fluctuations. According to the Minority Game, a financial market is inherently critical in that it typically exhibits a transition between a predictable and an unpredictable regime. Interestingly, taking variations in trading volume into account, fluctuations generated by this game are realistic in the sense of stylized facts, provided that this system is close to this critical point. This suggests

that according to the Minority Game, a financial market has to be regarded as a self-organized critical system.

The structure of this book mirrors the variety of perspectives and results of Minority Games: The first part is a highly enlightening and intuitively written survey about the development of and recent results about the Minority Game(s), while the second offers a collection of original research papers.

The Minority Game should be regarded as a step toward or even as a new paradigm in economics. Since its invention by the physicists Damien Challet and Yi-Cheng Zhang in 1997, it has gained tremendous resonance even outside the econo-physics community. The Minority Game must be clearly distinguished from mainstream economic reasoning with respect to the questions posed, the assumptions made, as well as methods used. Thereby it should be kept in mind that its fundamentals such as inductive reasoning and bounded rationality are economic ones, founded by well-distinguished economists such as B. Arthur (1992) and H. Simon (1981), respectively. This book does not just provide insights into some model, but rather provides an enlightening guidance into a whole universe of ''Minority Games''. This is manifested in the structure of the book itself which, in the first part, leads the reader successively from general, historical and economic notes into increasingly detailed formal setting, and, in the second half, documents the evolution of this idea by providing a collection of important papers in this context. The introduction is highly recommended as a fair and deep overview and discussion with many valuable remarks.

The axiomatic theory of general equilibrium has dominated economic reasoning since its publication in 1954 by K. Arrow and G. Debreu, even though in 1972 works by R. Mantel and H. Sonnenschein and 1974 by G. Debreu himself showed that this theory has too little structure to have strong explanatory power. Critical estimation of the underlying assumptions serving as axioms of this theory have among others led to the emergence of psychologically motivated characteristics to model individual trading decisions. The Minority Game takes a radically different viewpoint. This is not only due to the fact that the Minority Game was invented and analyzed first by physicists whose focus often differs from economic ones. In contrast to main stream economics, where agents are supposed to reason deductively and be completely rational, agents in the Minority Game are inductively reasoning and bounded rational with only reduced information. The Minority Game focuses on statistical charac-

teristics of highly speculative financial markets instead of purely fundamental markets.

Bounded rationality and heterogeneity have been shown to produce behaviour that resembles empirical data well. The problem is that the corresponding models are uncontrollably complex since the number of degrees of freedom is large, while the interaction is nonlinear. To avoid this danger, the deduction of the Minority Game proceeds in a far reaching series of abstractions and subtile simplifications to uncover essentials of financial markets. It is a special case (symmetric and binary) of the El Farol Bar Game invented by B. Arthur in 1997, but differs from it with respect to its objective. While the original El Farol Bar considers an inductive thinking path to equilibrium, the Minority Game is concerned with understanding the origin of fluctuations around this equilibrium. The focus on fluctuations corresponds to the viewpoint that the collective behavior of financial markets is a result of how fluctuations propagate through interactions from the micro to the macro scale. Furthermore this focus agrees with the existence of "universal" statistical properties, so-called stylized facts observed on different markets, that are largely independent of particular details of market constituents and hence provide representative information about the dynamics of the system irrespective of details concerning micro market structure or individual trading decision processes.

The Minority "Game" is not a game in the game theoretic sense. The idea that interactions are due to "agents act against agents" is at the core of mainstream economics. Consequently, Game Theory has become an important mathematical and conceptual tool. Game theory provides workable models for small numbers of agents, who are interacting with each other in pair-wise manner. In real world financial markets, the number of agents is large. Therefore, the value of game theory appears to be limited in the presence of a large number of players. Tools of statistical physics become applicable in the limit of huge sets of agents and are thus well suited to this situation.

Similar to traders "trading" against the market, the perspective of the Minority Game is that agents "play" against the crowd, not against individual agents. This approach has a clear foundation in the seminal works by Erdos and Renyi who invented the "probabilistic method" to solve large combinatorial problems. The existence of so-called "typical properties", i.e., properties that each possible realization of a random system possesses with probability 1, is of essential importance. Typical properties become more sharply visible if the system size grows to

infinity. Thus, the larger the system is the more "regular" it becomes in the sense that fluctuations become small. This self-averaging property is at the very bottom of the treatment of complexity in the Minority Game to characterize collective behavior. It also provides a logical justification for the Minority Game setting, where in contrast to the game theoretic "player vs. player" setting, each agent "plays" against the crowd as a trader trades "against" the market.

Does the Minority Game represent a financial market? The authors do not claim this. In fact, the Minority Game only covers particular features of real markets, as real markets in general have both a minority and a majority aspect. This is not a weakness, it rather corresponds to the modelling philosophy of successively enlarging an initially elementary model after having understood it in great depth. The elementary setting of the Minority Game allows for far reaching generalizations such that corresponding model class is not restricted to only a particular aspect.

This book is about a new way of reasoning and proves the value of an open-minded communication between such different cultures like economics and physics. While cooperation and mutual acceptance might be sometimes difficult on the "public" level, as the authors themselves say: "… in private venues, … the communication between economists and physicists is excellent and stimulating."

I highly recommended this book to all researchers in the filed of economics and physics. Its style makes it valuable not only for researcher from these areas. Its argumentation can serve as an example for a successful encounter of cultures. The value of the Minority Game is to offer a clear framework in which deep statements can be drawn rigorously, while allowing for far reaching extension. Therefore, the practical relevance is concerned with the increase of understanding.

Concerning the very title of this book "The Minority Games", the author hopes that, with his opinion on the Minority Game, he is not in the minority rather than in the majority.

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